Improved Performance of Optical Beam Steering through an InP Photonic Integrated Circuit

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Abstract: Optical beam steering through an InP photonic integrated circuit has been improved in term of side-lobe suppression (13dB from -14° to 14° around the peak) and steering angle (10° by 28nm wavelength tuning).

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1. Introduction

2D electronically controlled optical beam steering is envisaged to be very useful for light detection and ranging (LIDAR) [1-2]. In [2] we demonstrated an InP photonic integrated circuit (PIC) for this purpose. The critical part of the PIC is an optical phased array with embedded 2nd order gratings for emission vertical to the PIC plane. Wavelength is used to control the beam steering along the grating direction (longitudinal direction). An array of phase shifters is used to control the beam steering perpendicular to the grating direction (lateral direction). These two controls are independent of each other therefore a 2D beam steering can be realized. In [2] we demonstrated 10° of beam steering in the lateral direction and 5° in the longitudinal direction limited by the 40nm of wavelength tuning around 1550 nm. We also demonstrated 7-dB side-lobe suppression for the angle range from -14° to 14° around the peak. In this work we show that 13-dB side-lobe suppression has been achieved through controlling the amplitude of the emission across the array. We also show that through a 4-f lens system 10° of steering angle can be achieved in the longitudinal direction through 28nm wavelength tuning.

2. PIC layout and measurement setup

As shown in Fig. 1(a) the PIC consists of an input semiconductor optical amplifier (SOA) to compensate the coupling loss; a 1×2 MMI tree to split the input signal into 8 channels; SOAs and phase shifters (PS) in each channel to boost the signal power and control the signal phase; an emission array composed of SOAs with 2nd order gratings etched in the upper optical confinement layer of the waveguide core; and a monitor array which makes adjacent channels form interferometers to monitor the phase generated by the phase shifters. The emission from the emission array propagates downward through the substrate and an aperture opened in the bottom N-contact metal. The chip is mounted top-side up on an AlN carrier and then on a copper heat sink as shown in Fig. 1(b). Holes are opened in the carrier and the heat sink to allow the emission transmit through. Three lenses installed in lens tubes are used for the far-field imaging of which the first lens implements the Fourier transform and the second and third lenses project the far-field pattern onto an InGaAs infrared camera. Two lenses—one convex and one concave—can also be inserted above the first lens for far-field imaging to magnify the steering angle as introduced later on.

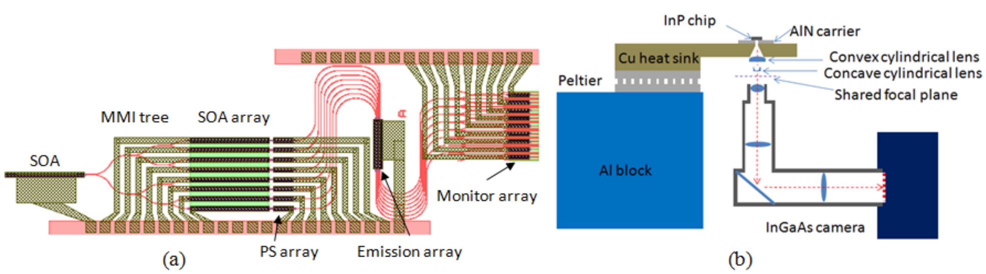

Fig. 1 (a) Schematic layout of the PIC; (b) Schematic of the measurement setup

3. Improved side-lobe suppression

In [2] we injected current into the SOAs in each channel through a single current source. Because the series resistance of these SOAs varies the current injected into each SOA is actually not the same which tends to make the amplitude of the emission across the array non-uniform and therefore harm the side-lobe suppression. To overcome the issue we use a strategy as shown in Fig. 2(a). We place two resistances in series for each channel before the connection to the SOA: one variable from 0 to 50Ω and one fixed at 10Ω. A single voltage source is used to inject currents into all the SOAs in the channels and the current into each channel is adjusted through varying the variable resistance and monitored by the voltage drop across the fixed resistance. Through this way we ensure 100mA current uniformly injected across all channels. After this we adjust the phase shifter currents to optimize the far-field pattern in the lateral direction as implemented in [2]. Fig. 2(b) shows the optimized result which is the field distribution across the peak in the longitudinal and lateral directions. A side-lobe suppression of 13dB has been successfully demonstrated from -14° to 14° around the peak which actually corresponds to the theoretical value very well if assuming the emission is uniform across the array.

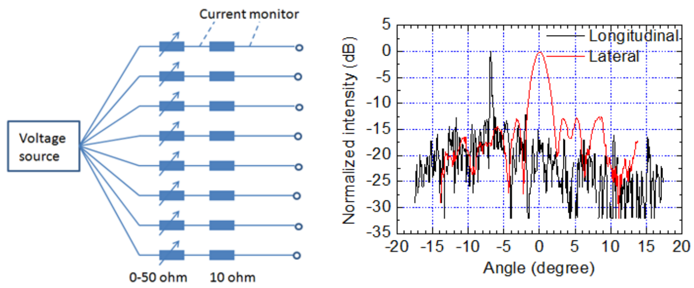

Fig. 2 (a) Schematic of the electrical setup for adjusting injection currents into the SOAs; (b) Optimized far-field pattern

4. Sweeping angle magnification through a 4-f system

To increase the sweeping angle in the longitudinal direction another 2 cylindrical lenses are inserted between the PIC and the lens for the Fourier transform as shown in Fig. 1(b). The sequence is a convex lens first followed by a concave lens. These two lenses share the same focal plane and the effective focal length of the convex lens is M times that of the concave lens. In our case according to the lens spec M equals 2.56. Theoretically we would expect an M times magnification of the steering angle. When the steering angle being magnified the beam divergence will also be magnified by the same amount. The experiment results are shown below where Fig. 3(a) plots the peak position in the longitudinal direction versus wavelength. We can see that the slope is 5.6° per 40 nm before inserting the 4-f system and is increased to 14.3° per 40 nm after. The magnification is therefore 2.55 which is in good agreement with the theoretical prediction. Fig. 3(b) shows the far-field distribution in the longitudinal direction. Without or with the 4-f system the beam divergence angle (full width at half maximum) is 0.2° and 0.5°, respectively. So a magnification of 2.5 times is seen which is also close to the theoretical prediction. With the angular magnification a 10° steering angle can therefore be achieved through 28nm wavelength tuning.

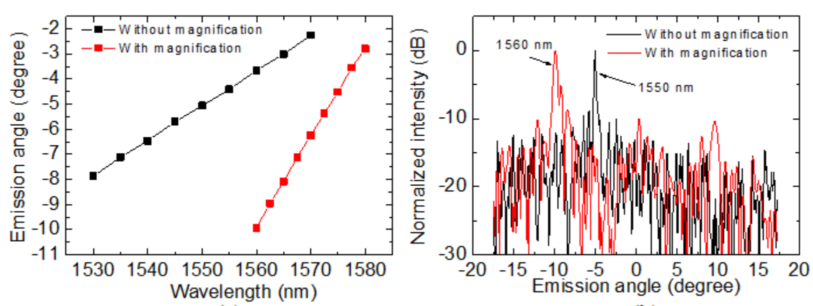

Fig. 3 (a) Peak position in the longitudinal direction versus wavelength; (b) Field distribution in the longitudinal direction.

5. Summary

In summary we have demonstrated improved performance of electronically controlled 2D beam steering from an InP PIC. Through controlling the emission across the array we demonstrated improved (13 dB) side-lobe suppression. We also demonstrated wider steering angle in the longitudinal direction through inserting a 4-f lens system.

6. Reference

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